National Aeronautics and Space Administration

EDL Instrumentation Workshop

Background and Motivation

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August 18, 2015

www.nasa.gov/spacetech

Outline

Why this Workshop; what is the Objective?

How Will We Proceed?

- Agenda and Products

Background and Context

- Brief history of EDL Instrumentation
- NTEC Memo
- Discovery 14 Engineering Science Investigation (ESI) Requirement

Upcoming Opportunities and Timing (Context)

Why this Workshop?

Objective: Scope out a *low-cost* instrumentation effort for Discovery and/or New Frontiers-class missions, including acquisition strategy, for FY17-19 (TBR). This is intended to be a new Game-Changing project.

- MEDLI and MEDLI2 cost $25-$30M each
- These costs are not sustainable
- Solutions are too massive and large for small planetary missions

Share various perspectives and previous experiences; discuss costs

Establish the future mission needs and measurement/sensor priorities

Determine the best acquisition and phasing approach

This is a *<u>working</u>* meeting—please participate actively.

Agenda Day 1 (Tuesday)

Time	August 18	Presenter
8:00 – 8:30	Workshop Registration	
8:30 – 9:15	Background/Motivation "State of work and where we need to go" NTEC memo, Discovery ESI requirement, mission context (NF AO, next Discovery, etc.) Overview of completed and in place EDL projects	Michelle Munk (45 mins)
9:15 – 9:45	Ablative TPS and Base Mission Required Instrumentation	Ethiraj Venkatapathy (30 min)
9:45 – 10:15	MEDLI - **Mars Science Laboratory** Entry, Descent, and Landing Instrument - Overview of completed project, Instrumentation	Michelle Munk (30 min)
10:15 – 10:30	Break	
10:30 – 11:00	MEDLI2 - **Mars Science Laboratory** Entry, Descent, and Landing Instrument 2 Overview of current project	Deepak Bose (30 min)
11:00 – 11:30	EFT-1 - Exploration Flight Test 1 Overview of completed project & Instrumentation	Brandon Smith
11:30 – 12:30	Lunch	
12:30 – 1:30	EFT-1, EM-1 Instrumentation and Challenges Beyond (ITAR)	Joe Olejniczak (1hour)
1:30 – 2:30	IRVE-3 - Inflatable Reentry Vehicle Experiment 3 Overview of completed project & instrumentation (ITAR)	Robert Dillman (1hour)
2:30 – 2:45	Break	
2:45 – 3:30	SBIR Awards – Phase I, Phase II, CRP (ITAR)	Robin Beck (20 Mins) Brandon Smith (20 Mins) X
3:30 – 4:15	DoD Experience – Army Hypersonic Testing Instrumentation – (ITAR)	Gerald Russell

Agenda Day 2 (Wednesday)

Requirements Formulation of Low-Cost Discovery Class EDL Instrumentation

Time	August 19	Presenter
8:00 – 8:30	Cost Drivers – Minimal cost, mass, volume - Electronics	Henry Wright via Teleconference (30 Min)
8:30 – 9:00	Distributed Data Systems for TPS	Steve Horan (30 min)
9:00 – 9:30	Commercial sources	Nick Trombetta/Steve Horan (30 min)
9:30 – 9:15	Break	
9:45 – 4:00	**Project Formulation**	
9:45 – 10:45	Measurement Priority Discussion (Review Discovery document)	Jason Lechniak
10:45 – 11:45	Measurements Requirements Discussion (Review Discovery document)	Jason Lechniak
11:45 – 12:45	Lunch	
1:00 – 2:00	Acquisition Strategy Discussion	Jason Lechniak
2:00 – 3:00	Product Phasing Discussion	Jason Lechniak
3:00 – 3:15	Break	
3:15 – 4:00	Competed vs Directed Tasks Discussion (avionics, sensors, testing in materials, qualification)	Jason Lechniak
4:00 – 4:30	**Sketch Potential Project**	Jason Lechniak
4:30 - 5:00	Wrap-Up, Next Steps	Michelle Munk

Brief History of EDL Instrumentation

Missions that involve entering planetary atmospheres are rare opportunities to collect relevant EDL flight data

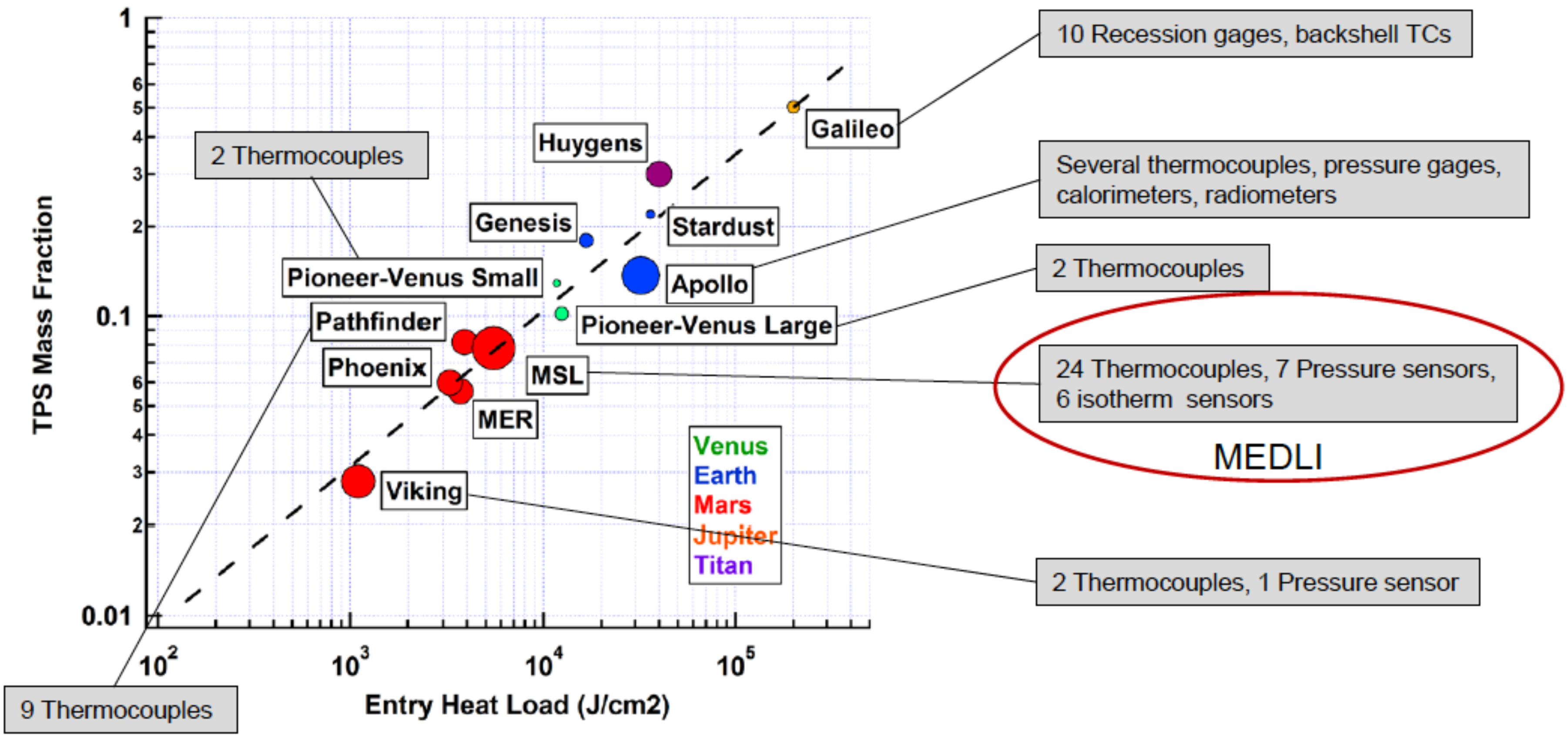


Chart credit: Deepak Bose/ARC. Circle sizes represent relative vehicle diameter. EFT-1 not shown.

Recent Progress

- In 2006, NASA Administrator Michael Griffin identified Stardust and Genesis sample return capsules as missed opportunities regarding EDL instrumentation. This led to the inclusion of MEDLI on MSL.

- EFT-1 included NASA-furnished heatshield instrumentation (pressures and thermal plugs), building on the experience of implementing MEDLI.

- In April 2014, the NASA Technology Executive Council (NTEC) signed a memo agreeing to meet at the beginning of new EDL missions, to determine if and how to instrument missions (programmatically).

- The Discovery 2014 AO includes a requirement that any mission performing EDL must include instrumentation (the “Engineering Science Investigation,” ESI)
    - It is implied, but not decided, that SMD will pay for the Discovery instrumentation, if an EDL proposal is selected
    - Since the SMD budget is limited, the data return may be minimal, or co-funding may be necessary
    - Selection expected within a couple of months

Expected New Frontiers-4 Missions with EDL

From the Planetary Decadal Survey, 2011

Comet Surface Sample Return

- The objective of this mission is to acquire and return to Earth a macroscopic sample from the surface of a comet nucleus using a sampling technique that preserves organic material in the sample.

Lunar South Pole-Aitken Basin Sample Return

- The primary science objective is to return samples from this ancient and deeply excavated impact basin to Earth for characterization and study.

Saturn Probe

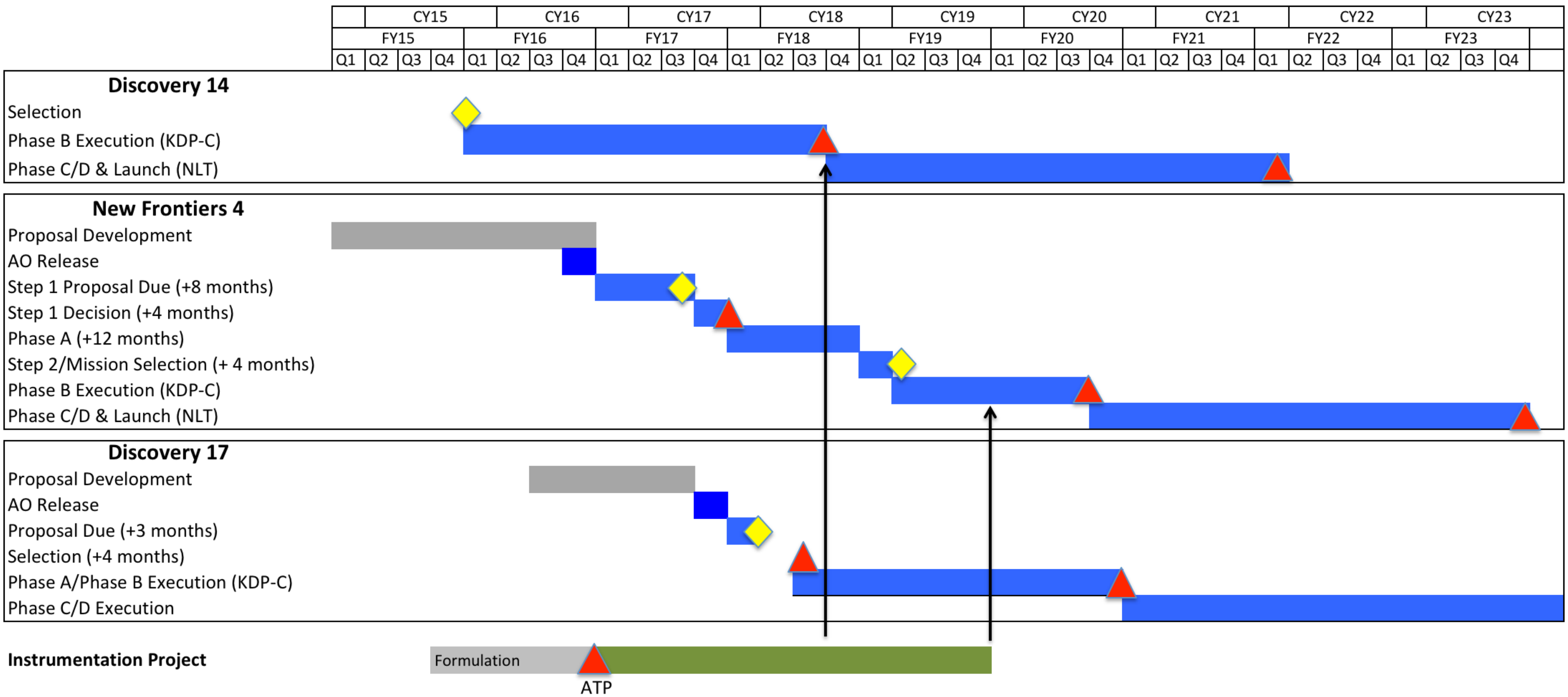
- This mission would deploy a probe into Saturn's atmosphere to determine the structure of the atmosphere as well as noble gas abundances and isotopic ratios of hydrogen, carbon, nitrogen, and oxygen.

Venus In Situ Explorer

- The primary science objectives of this mission are to examine the physics and chemistry of Venus's atmosphere and crust. The mission attempts to characterize variables that cannot be measured from orbit, including the detailed composition of the lower atmosphere, and the elemental and mineralogical composition of surface materials.

AO Release by end of 2016

Notional SMD Mission Schedule



Related EDL Technology Activities

New Materials

- HEEET – new, woven TPS development underway
  - Incentivized in Discovery AO
  - TRL6 by end of 2017 – 1-meter scale engineering test unit
  - Efforts underway to have HEEET incentivized for New Frontiers
  - Instrumentation is *not part of the development project*
- Conformal TPS (PICA-based) – funded at low level
  - Successful SPRITE arcjet tests demonstrate robustness
  - Scale-up efforts underway; could be used for CASIS Terrestrial Return Vehicle (TRV), for Orion backshell, and for planetary backshells
  - On track to be applied to TVA capsules

New Vehicles (possible use as testbeds)

- Maraia – JSC small-scale, truncated Soyuz (sounding rocket 10/2015)
- Terminal Velocity Aerospace (TVA) vehicles- RED-Data and RED-4U
- Terrestrial Return Vehicle (TRV) – Mid-L/D vehicle, ISS return

Related EDL Activities (2)

New Systems for Application to Human Mars Missions

- HIAD – flexible TPS, deployable structure; stowed for cruise
  - Performed 2 suborbital flight tests at 3-m scale
  - 6-m wind tunnel and pack/deploy tests
  - Scale-up and orbital entry are next challenges
- ADEPT – Mechanical deployable with carbon cloth aeroshell
  - 2-m laboratory model stow/deploy tests
  - 0.7-m wind tunnel test
  - Sounding rocket test is next challenge
- Mid-L/D – Large rigid body with TPS
  - Will likely have control surfaces
  - Will likely be a more complex shape (compared to a blunt body)

- These systems require instrumentation planning early to maximize ground-to-flight traceability

General EDL Instrumentation Objectives

Increase Overall EDL Data Collection Compared to Historical Missions

Aerothermal Environment and TPS
- Improve understanding of the aerothermal environment
- Measure aerothermal heating
- Measure TPS response to the flight environment
- Determine TPS-to-structure bond integrity/TPS flaws

Atmosphere, Aerodynamics and Flight Dynamics
- Improve landing accuracy
- Verify full flight vehicle aerodynamic parameters across multiple regimes

Parachute/Deceleration Performance
- Improve landing modeling and accuracy

Vehicle Structure
- Reduce vehicle mass

Increase Vehicle Reliability and Performance for future Missions

Measurement Objectives
As Stated in the ESI Requirements Document

Technical Objectives	Quantity/Measurement	Accuracy
Aerothermal Environment and Thermal Protection System (TPS)		
Aerodynamic heating	Heat Flux – Forebody	±5%
	Heat Flux – Afterbody	±10%
Reduced TPS and vehicle mass, reduced subsystem risk for future missions	In-Depth Temperatures, as a function of time at multiple locations	±15%
	Recession in Flight (multiple locations)	±2 mm
	Final Recession (if recovered)	±1 mm
Demonstrate adequate bonding and bondline integrity	TPS-to-structure bondline visualization (before and after flight)	±0.5 mm
Atmosphere, Aerodynamics, and Flight Dynamics		
Reconstruct EDL including atmospheric density. Increase landing accuracy.	Inertial Rates (IMU), mass properties	varies
	Static pressure on vehicle surface at stagnation point	±0.5% FS
Determine vehicle attitude in hypersonic regime	IMU, mass properties, and static pressure on vehicle surface at multiple locations	Pressure ±0.5% FS
Verify aerodynamic coefficients in hypersonic and supersonic regimes; winds in the supersonic regime	IMU, mass properties, and static pressure on vehicle surface at multiple locations	Pressure ±0.5% FS

discovery.larc.nasa.gov/pdf_files/EDL_Instrumentation_ESI_GO_061514_Final.pdf

Measurement Objectives (2)
As Stated in the ESI Requirements Document

Technical Objectives	Quantity/Measurement	Accuracy
Atmospheric Decelerator		
Enhance system capability (heavier payloads, higher altitudes, etc.), reduce mass, increase reliability and performance for future missions	Aero decelerator total angle of attack at start of inflation	±2°
	Observations of aero decelerator area oscillations	30 fps
	Aero decelerator force-time history	±2% of force @ 60 Hz
	Aero decelerator angles of attack and sideslip vs. time	±1° @ 30 Hz
	Aero decelerator drag coefficient vs. time and Mach number	±4% @ 60 Hz
Vehicle Structure		
Reduce mass, increase reliability and performance for future missions	Entry Loads	±10%
	Landing Loads	±10%

Measurement Priorities
As Stated in the ESI Requirements Document

Measurement Objective	Earth Entry-Ballistic	Earth Entry-Lifting	Mars Entry-Ballistic	Mars Entry-Lifting	Venus Entry	Outer Planet Entry	Titan Entry	Relevant Sensors/ Instrumentation/ Data
Aerothermal Environment and TPS								
Aerothermal Environment	M	M	H	H	H	H	H	Near-surface thermocouples, heat flux sensors
TPS Response	M	M	H	H	H	H	H	In-depth thermocouples
TPS Recession/Mass Loss	L	L	L*	L*	M*	H	L*	Recession sensors
Gas-cap Radiation	H	H	M	M	H	M	L	Radiometers, airborne observation on Earth return
Pre-Flight Vehicle Characterization	H	H	M	M	M	M	M	CT-Scan, laser scan, bond verification, etc.
Post-Flight Vehicle Characterization	H	H	n/a	n/a	n/a	n/a	n/a	CT-Scan, laser scan, TPS cores, bond verification, etc.
Airborne Observation	H	H	n/a	n/a	n/a	n/a	n/a	Infrared Imaging, TPS seeding sensors

H=high priority, M=medium priority, L=low priority, *=may be higher, depending on material, entry speed

Measurement Priorities (2)
As Stated in the ESI Requirements Document

Measurement Objective	Earth Entry-Ballistic	Earth Entry-Lifting	Mars Entry-Ballistic	Mars Entry-Lifting	Venus Entry	Outer Planet Entry	Titan Entry	Relevant Sensors/ Instrumentation/ Data
Atmosphere, Aerodynamics, and Flight Dynamics								
Atmospheric Density, Dynamic Pressure	L	L	M	M	M	M	M	IMU, high-speed surface stagnation pressure transducer
Vehicle Attitude, Aerodynamic Coefficients	L	L	M	L	M	L	M	IMU, multiple surface pressure transducers
Atmospheric Decelerator								
Parachute/Decelerator Performance	L	L	H	H	M	M	M	IMU, surface pressure transducers, camera(s)
Vehicle Structure								
Entry Loads	M	M	M	M	M	M	M	IMU, load cells

H =high priority, M = medium priority, L = low priority
*** = May be higher, depending on material, entry speed**

Summary

- The need and timing is right, to produce a low-cost instrumentation system.
  - New Frontiers is fully expected to have an instrumentation requirement.
  - Orion EM-2 suite will have to be planned in the next year or so; they are mass-challenged

- Things to consider, as we plan this project:
  - What can we do with labor only, in 2016?
  - What is the right balance/phasing of a low-cost version of bare minimum instrumentation, versus more advanced development?